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CONTACT RESISTANCE IN SILICON CARBIDE CONTACTS

Masaharu Namba[1]

ABSTRACT: Referring to metal - and SiC-SiC contact characteristics, potential energy of an electron in SiC surface is discussed and volt-ampere characteristics of SiC-SiC contact are derived for which the existence of both space charge and oxide layer is considered. In order to avoid the tunnelling mechanism of the current flow, assumptions are made that the potential of the latter is nearly equal to that of the former, ϕ_0, and the motion of the electron through these barriers is described by diffusion theory.

1. Introduction

Attempts have been made to explain the nonlinearity of the silicon carbide contact resistance by a number of theoretical arguments. The basic point in these explanations is that the potential of the oxide film on the surface of silicon carbide (SiC) is higher than the thermal energy of the carrier in the bulk of the SiC. The calculations are then based on the assumption that the current is carried through this thin film by the carrier passing through it as a result of the tunnel effect [1]. The contact resistance is assumed to be totally dependent on the thickness of the surface film, but the calculated resistance is completely inconsistent with empirical measurements of the film. It has been recently proposed that there is a space charge layer present on the free surface of the SiC which is dependent on the surface state. Calculations based on this hypothesis have been presented for the cases where the carrier crosses this barrier thermally, [2], as well as for those in which the carrier crosses as a result of the tunnel effect. These theories fail to take into consideration the presence of the oxide layer, which has been clearly defined by electron diffraction. In the present study, SiC surface potentials have been postulated from a study of metal-SiC contact potentials, and the effects of oxide layer thickness on surface resistance changes in silicon carbide, and the voltage-current characteristics of a SiC-SiC contact have been derived from these results. /602[2]

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[2] Numbers in the margin indicate pagination in the foreign text.

2. Contact Characteristics

The materials used for the experiment were black SiC, green SiC, and colorless SiC[1] crystals, the intrinsic resistances of which were 0.1, $10 \sim 10^2$ and 10^4 ohm cm, respectively.

2.1 Metal - SiC

When semiconductors and metals are brought into contact they both maintain equally high Fermi levels in an equilibrium state. Thus, the electric current during rectification depends on the work function differential ϕ_0 between the metal and the semiconductor as in the formula exp (ϕ_0/kT). Accordingly, the current is affected to a considerable extent by the work function f of the metal while the ϕ_0 differential in n and p types of SiC is generally proportional to the width of the forbidden band. Table 1 gives the ϕ_0 and rectification characteristics as determined by the C.P.D. method.

TABLE 1. SiC-METAL CONTACT POTENTIAL AND RECTIFICATION CHARACTERISTICS OF SIC DIODES

	Metal work function	Al 4.14	Mo 4.20	W 4.52	Fe 4.70	Pt 5.32	Phosphor bronze
black SiC	ϕ_0 (eV)	−0.50	−0.50	−0.50	−0.50	−0.50	−0.50
	$i_f(\mu A)$ at $V=0.5$†	5	7	10	8	15	6
	i_f/i_b† at $V=2$	10	12	15	12	15	10
green SiC	ϕ_0 (eV)	+0.50	+0.55	+0.60	+0.60	+0.65	+0.60
	$i_f(\mu A)$ at $V=0.5$	0.61	0.53	0.40	0.30	0.40	0.45
	i_f/i_b at $V=2$	3×10^3	5×10^3	8×10^3	4×10^3	7×10^3	1×10^3
colourless SiC	ϕ_0 (eV)	−0.55	−0.50	−0.55	−0.55	−0.45	−0.55
	$i_f(\mu A)$ at $V=0.5$	2.1×10^{-3}	1.8×10^{-3}	2.0×10^{-3}	1.5×10^{-3}	1.0×10^{-3}	2.0×10^{-3}
	i_f/i_b at $V=2$	2×10^2	8×10^2	5×10^2	7×10^2	6×10^2	1×10^3

† i_f: forward current, i_b: back current.

It is evident from this table that there are no differences in ϕ_0 or variations in the current which can be attributed to the metal and it is clearly apparent that the ϕ_0 differential of n and p type SiC is much too small, given the width of the forbidden band (ΔE_G = 2.0eV) [4]. It would

[1] For the purposes of simplicity, these compounds are given as B.C., G.C., $C_L \cdot C$, respectively.

therefore be appropriate to consider that a Schottky barrier is formed by a trapped charge on the free surface of the SiC in the same manner as occurs in Si, Ge, etc., in a similar surface state. Its level may be accepted as being ± 0.5 ~ 0.6 eV.

2.2 SiC-SiC

The surfaces of the test material were abraded with # 220 G.C. grain, then further polished with an oilstone. Point contacts were used and silver paste was used in the electrodes. Specifically, a V-shaped crystal with a base width of 0.3 ~ 0.4 cm and a height of 0.5 cm was brought in contact at a constant pressure with another SiC plate (basal 0001 plate, 0.5 χ 0.3 ~ 0.4 cm^2) for the purpose of making the measurements.

2.2.1 P Type C_L C. Plate-p Type B.C. Point

The V-i characteristics were measured by the static method. All contacts were of the rectifier type as shown in Table 2. Except for the fact that rectification was somewhat lower when metal was used in place of B.C., /604
virtually the same results were obtained in both cases.

TABLE 2. C_L·C. PLATE-B.C. AND METAL POINT CONTACTS.

whisker	Phosphor bronze	B. C.
V_f	i_f μA	i_f μA
0.5	1×10^{-3}	$0.5\sim1.5\times10^{-3}$
1	6×10^{-3}	$2\sim7\times10^{-3}$
3	8.6×10^{-2}	$2.6\sim9.6\times10^{-2}$
V_b	i_b μA	i_b μA
4	0.6×10^{-3}	$1.6\sim5\times10^{-3}$
10	6×10^{-3}	$1.35\sim3.6\times10^{-2}$
20	6.2×10^{-2}	$1.1\sim3.5\times10^{-1}$

If the presence of a space charge barrier is given, as suggested in Section 2.1, virtually all of the voltage drop may be taken as occurring on the high resistance side (C_L·C.).

2.2.2 N Type G.C. Point - p Type B.C. Plate

The rectification characteristics (R-V characteristics) shown in Figure 1 were obtained.

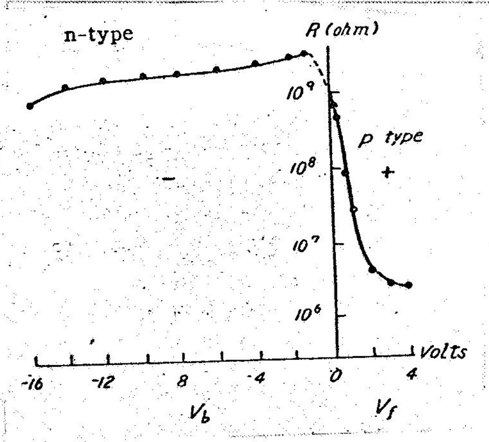

Figure 1. Rectification Characteristics of p-n Type SiC Contact.

As has been stated above, the width of the forbidden band in the case of SiC increases relative to the increase in kT. Thus, the ratio of the minority carrier to the majority carrier concentration:

$$f = \exp(-\Delta E_G/kT)$$

is quite small. On this basis, it is believed that the current flows through the contact boundary as a result of the process of recombination [5].

2.2.3 n Type G.C. - n Type G.C.; p Type B.C. - p Type B.C.

The V-i characteristics are usually written as $i = AV^n$ in this type of contact. The value of n, however, varies with the applied voltage and is also different for B.C. and G.C. Our measurements for a B.C. - B.C. contact were:

$$i \propto V \qquad V = 0 \sim 0.5 \text{ volt}$$
$$i \propto V^{1\sim 6} \qquad V = 0.5 \sim 20 \text{ volt}$$

In the case of a G.C. contact, they were:

$$i \propto V \qquad V = 0 \sim (0.5 \sim 2) \text{ volt}$$
$$i \propto V^{1\sim(2.5\sim 4.5)} \qquad V = (0.5 \sim 2) \sim 30 \text{ volt}$$

An impulse voltage of the order of 20 μ s was read at the higher current levels.

3. Variations in Contact Resistance as a Function of Oxide Film Thickness

As indicated above, it has become apparent that the space charge barrier must be taken into consideration in any discussion of SiC-SiC contact. On the other hand, a large number of electron diffraction images show that the surface of the SiC is covered with an oxide film (amorphous quartz) [6]. It is possible to determine the mechanism by which the carrier passes through this oxide film by determining the variations in contact resistance as a function of the film thickness δ. Accordingly, the correlation between contact resistance R_c with varied SiO_2 film thicknesses, secured through the application of surface treatment, was investigated at low voltages (within the limits in which i is proprotional to V). Since the individual deviations in single crystals are large, the measurements were made using 20 grams of # 100 B.C. powder which was packed into a 30 mmϕ tube under 100 kg/cm^2 of pressure. The deviations were within ±10% or less. Since $\delta \leq 3 \times 10^{-8}$ when the SiC surface is etched with hydrogen fluoride, it was postulated that $\delta = 10^{-8}$ cm. The δ for the other specimens was calculated on the basis of weight increase when the powder was oxidized [7]. The results obtained are given in Figure 2.

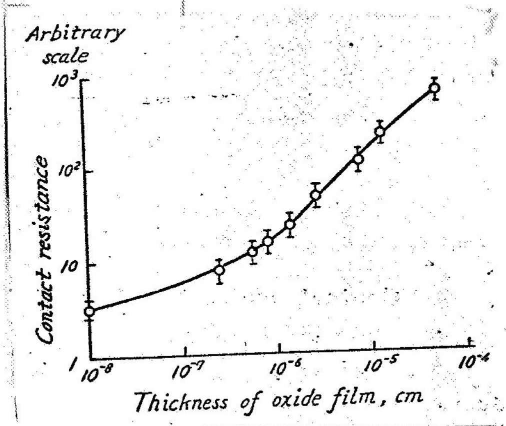

Figure 2. Variation of Contact Resistance With the Thickness of Oxide Film.

As Figure 2 indicates, considerable deviations were present when δ was smaller than 10^{-7} cm, but at thicknesses of 10^{-6} cm or more a fully proportional correlation between R_c and δ was maintained. The form of the electrical current through this layer is controlled by the magnitude of the SiO_2 layer potential. If the base of the conduction band has an eV several times greater than that of the SiC, the barrier transition of the carrier must be caused by the tunnel effect. If this is the case then the V-i characteristics, for $eV \gg kT$, are [8]:

$$i = en_0\sqrt{kT/2\pi m}\,\exp\left[-\frac{4\sqrt{2m}}{3\hbar}\frac{\delta}{eV}\times\{\phi_0'^{3/2}-(\phi_0'-eV)^{3/2}\}\right]$$

In the above equation, n_0 is the free carrier density in the bulk of the SiC and ϕ_0 is the difference between the work function of the SiC and the electron affinity of the oxide film. Accordingly, the current at low voltages such as those obtained when $\phi_0 \gg eV$ drops with the reduction in θ as:

$$\exp\left[-\frac{2}{\hbar}\sqrt{2m\phi_0'}\,\delta\right] = 10^{-8.86\times10^7\delta} \qquad (\phi_0' = 4\text{ eV})$$

However, the rapidity of such a change is completely inconsistent with the empirical data shown in Figure 2. We believe that the form of the current is totally unrelated to the tunnel effect, but that ϕ_0 is small enough such that the carrier is able to pass through the film as a result of thermal energy effects.

Mott [9] has shown that a considerable current will still flow between a metal and the insulating material even though the field is quite weak. /605 Our problem can be considered in the same terms as those suggested by Mott, when there is no space charge layer.

For the purpose of simplicity let us consider n-type SiC. If one of the SiC-SiO_2 contact points in a SiC-SiO_2-SiC contact is selected (see Figure 3a), the magnitude of the potential $\phi(x)$ at point x is

$$\varphi=\phi_0'+\frac{2kT}{e}\log\left\{\cos\frac{2\pi e^2}{\kappa' kT}\times\lambda(x-\delta/2)\Big/\cos\frac{2\pi e^2}{\kappa' kT}\frac{\delta}{2}\right\} \quad 4$$

$$n_B=\frac{2\pi e^2}{kT}\lambda^2\sec^2\frac{\pi e^2}{\kappa' kT}\lambda\delta$$

In the above equation, n_B is the electron density within the oxide film when x = 0 and k' is the conductance of the oxide film.

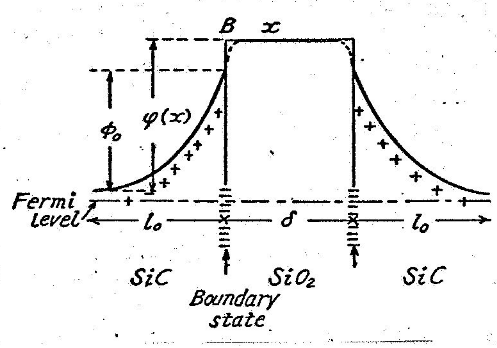

Figure 3a. Energy Level Diagram for a Grain Boundary at Equilibrium.

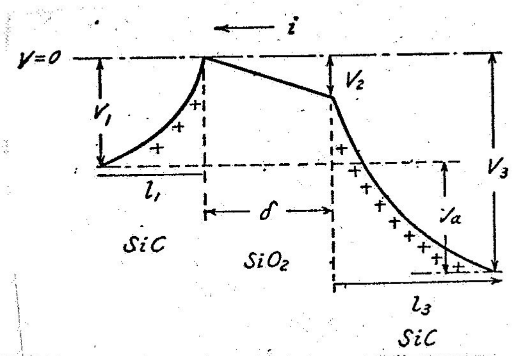

Figure 3b. Energy Level Diagram for a Grain Boundary Under an Applied Voltage V_a.

We must also take the space charge layer into consideration. As stated in Section 2.1, the potential at the SiC free surface is just ϕ_0 higher than the potential in the bulk of the SiC. Then, if these three barriers are considered separately, ϕ_0 is higher by just that amount due to the Schottky barrier.

$$\varphi(x)=\phi_0+\phi_0'+\frac{2kT}{e}\log\left\{\cos\frac{2\pi e^2}{\kappa' kT}\times\lambda(x-\delta/2)\Big/\cos\frac{2\pi e^2}{\kappa' kT}\lambda\frac{\delta}{2}\right\}$$

In order to obviate consideration of the tunnel effect, let us assume that $\phi_0' = 0$. Since in this case it is probable that n_B is $10^{19}e^{-\phi_0/kT} = 10^{10}\,cm^{-3}$, when $\phi_0 = 0.55eV$:

$$(\pi e^2/\kappa' kT)\lambda\delta \ll 1 \quad \text{for } \delta=10^{-8}\sim10^{-5}\,\text{cm}$$

[4] In this instance since x = δ/2, the boundary conditions were such that the field equalled 0, the conditions are slightly different to those applied by Mott.

It may thus be assumed that $\phi(x)$ is equal to ϕ_0 through the entire oxide layer.

4. Calculation of Voltage--Current Characteristics

The surface potential of SiC is now evident from Sections 2 and 3, and we now calculate the V-i characteristics based on the preceding data. The following assumptions are made for this purpose:

a. There is a Schottky barrier in the free surface of the SiC.

b. The magnitude of the potential of the film on the surface of the SiC is as high as the Schottky barrier.

c. The carrier passes through these various barriers in accordance with the diffusion theory. The diffusion theory is applicable when the mean free path of the carrier is low relative to the thickness of the barrier. The nuclear density of the impurities in B.C. and G.C. is of the order of $10^{20} \sim 10^{19}$ and $10^{17} cm^{-3}$ respectively, while the corresponding mobilities are ~6, and ~80 cm^2/volt-sec. On this basis, the thickness and the mean free path through the Schottky layer are ~4×10^{-7} and 7×10^{-6} cm, and 4×10^{-8} and 5.5×10^{-7} cm, respectively. These values fall within the limits in which the diffusion theory is applicable but this mobility may also be defined in terms of the Schottky layer. It is also assumed that the same mobility may be assumed in oxide layers of over 10^{-7} cm thick.

The potential is then measured using the barrier apex with one of the contact points as the base. An electron energy diagram at a voltage V_a is given in Figure 3 based on this model. The surface state is formed by the negative space charges (-q) in the space occupied by the electrons, while the Schottky barrier is formed by the positive space charges (+q) in the space charge region on the free surface of the SiC. The potential drop in the Schottky barrier may be derived by the applications of Poisson's equation. i.e:

$$V_1 = -2\pi e N l_1^2/\kappa$$
$$V_3 - V_2 = -2\pi e N l_3^2/\kappa$$

The total charge of this barrier is clearly:

$$Q = eN(l_1 + l_3) \tag{3}$$

Also the potential drop in the oxide layer with a current of i is:

$$V_2 = -\frac{2}{3}\sqrt{\frac{8\pi i}{\kappa' \mu'}}\{(\delta + x_0)^{3/2} - x_0^{3/2}\} \tag{4}$$

However,

$$x_0=\kappa' i/8\pi\mu' n_B{}^2 e^2,$$

where μ' is the electron mobility within the oxide layer and n_B is the electron density in the left side of the $SiC\text{-}SiO_2$ boundary. Since $\delta \ll x_0$ when $\delta = 10^{-8} \sim 10^{-5}$ cm, equation (4) may be rearranged and approximated so that:

$$V_2=-\frac{i}{n_B e\mu'}\delta \tag{4$'$}$$

It is therefore possible to derive from equations (1), (2), (3), and (4)' the relations

$$l_1=\frac{Q}{2Ne}-\frac{\kappa}{4\pi Q}\left(V_a-\frac{i}{n_B e\mu'}\delta\right) \tag{5}$$

$$l_3=\frac{Q}{2Ne}+\frac{\kappa}{4\pi Q}\left(V_a-\frac{i}{n_B e\mu'}\delta\right) \tag{6}$$

. In order to derive the V-i characteristics, we may solve the problem by considering three separate barriers under series current conditions. In accordance with the diffusion theory, the current density in the left side barrier is:

$$\begin{aligned} i&=e\mu E_1(n_B-n_0\exp(eV_1/kT))\\ &=\frac{e\mu}{L}\left[4\phi-\left(V_a-\frac{i}{n_B e\mu'}\delta\right)\right]\\ &\times\left\{n_B-n_0\exp\left[-\frac{e\phi}{kT}\left(1-\frac{V_a-\frac{i}{n_B e\mu'}\delta}{4\phi}\right)^2\right]\right\}\end{aligned}$$

where E_1 is the electrical field at the apex of the barrier, n_0 is the free electron density in the bulk of the SiC, $L = Q/eN$ and $\delta = \pi eNL^2/2k$.

When $x_0 \gg \delta$, the electron density at the apex of both of the boundaries is equal and the current in the Schottky barrier on the right side can thus be calculated in the same manner as above; and if it is given that both are equal then, for $-(V_3-V_2) + V_1 \gg kT/e$

$$i=\frac{e\mu}{L}\left\{4\phi+\left(V_a-\frac{i}{n_B e\mu'}\delta\right)\right\}n_B$$

$$\begin{aligned} n_B=\frac{n_0}{2}&\left(1-\frac{V_a-\frac{i}{n_B e\mu'}\delta}{4\phi}\right)\exp\\ &\times\left[-\frac{e\phi}{kT}\left(1-\frac{V_a-\frac{i}{n_B e\mu}\delta}{4\phi}\right)^2\right]\end{aligned}$$

When n_B is deleted from these equations and it is given that $V_a > A\phi_0\mu/\mu'\delta/L_0$, then the current is:

$$i=\frac{2\sigma\phi}{L}\left\{1-\left(\frac{V_a/4\phi-\mu/\mu'\ \delta/L}{1+\mu/\mu'\ \delta/L}\right)^2\right\}\exp\times\left(-\frac{e\phi}{kT}\left(1-\frac{V_a/4\phi-\mu/\mu'\ \delta/L}{1+\mu/\mu'\ \delta/L}\right)^2\right) \quad (7)$$

and when $V_a<4\phi_0\,\mu/\mu'\ \delta/L_0$, the current is:

$$i=\sigma(\mu'/\mu)\,e^{-e\phi_0/kT}\,V_a/\delta \quad (8)$$

The subscript "0" above indicates the value when $V_a = 0$, while σ represents the conductance of SiC.

It is further necessary to know the variations in Q as a function of V_a in order to determine the V-i characteristics. Stratton [2] postulates two types of surface states, one of which is an empty donor type and the other of which is a filled acceptor type. He then explains that the former absorbs the electrons which pass through the boundary. However, since the V-i characteristics are intimately dependent on the correlation $Q:V_a$, fully adequate results cannot be obtained. Since we are unable to derive a correlation on a theoretical basis we will attempt the empirical derivation described below.

The value for ϕ_0 may be obtained by a comparison between equation (8) and the current at low voltage. Since the contact surface is $\sim 10^{-6}\mathrm{cm}^2$, the value sought is on the order of ϕ_0 = 0.55eV between $\mu \sim \mu'$. This value is quite consistent with the height of the Schottky barrier as determined in Section 2.1.

a. Case of δ = 0.

This condition corresponds to the case in which the surface of the SiC is etched with hydrogen fluoride. In this case, equation (7) is simplified as:

$$i=\frac{2\sigma\phi}{L}\left[1-(V_a/4\phi)^2\right]\exp\times\left[-\frac{e\phi}{kT}\,(1-V_a/4\phi)^2\right] \quad (9)$$

This is the same as the equation derived from Taylor, et al. [10] for a Ge-Ge contact.

When Q maintains a constant value Q_0 independent of V_a, and $V_a = V_c = 4\phi_0$ = 2.2 volts, then the peak in the potential disappears. Further, if ϕ always maintains the value ϕ_0, Q will increase concurrently with V_a as

$Q=Q_0/2(1+\sqrt{1+V_a/\phi_0})$ and current saturation will be attained. These theoretical results do not in any way agree with the empirical measurements.

We will now assume that the correlation between V_a and Q is:

$$\alpha=Q/Q_0=\frac{1}{2}(1+\beta\sqrt{1+V_a/\phi_0}) \tag{10}$$

Then let us derive β from the voltage V_c at which the peak on the right side disappears:

$$\phi_0(1+\beta\sqrt{1+V_c/\phi_0})^2=V_c$$

Since the β calculated in this way is always lower than 1, then α will never equal 1 when $V_a = 0$. Accordingly, we are forced to make gradual adjustments from the point at which $\alpha = 1$ (when $V_a = 0$) to α_{max} (the value when $V_a = V_c$) until $V_a = 0$. The correlation between α and V_a obtained in this way is given in Figure 4.

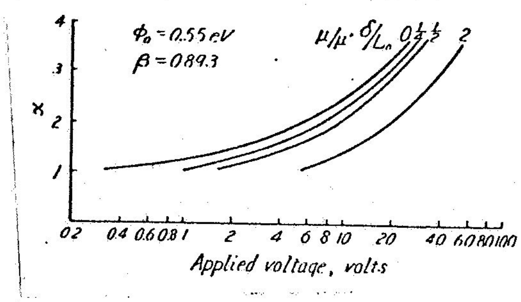

Figure 4. Variations of Total Space Charge With Applied Voltage (by eg. (10) and (12)).

b. <u>Case of δ = δ</u>

As shown in Section 2.2.3, the contact resistance in SiC-SiC shifts from ohmic to non-ohmic in the vicinity of /607
0.5 ~ 2 volts. In accordance with our hypothesis, this phenomenon can be derived from equation (7) and (8) and the inflection voltage V_i will be:

$$V_i=4\phi_0\,\mu/\mu'\,\delta/L_0 \tag{11}$$

In our test samples:

$$\phi_0=0.5\sim0.6\ \text{eV}$$
$$L_0=\sqrt{2\phi_0\kappa/\pi Ne}=8\times10^{-7}\quad\text{for B.C.}$$
$$=10^{-5}\quad\text{for G.C.}$$

When Vi = 0.5 volts, then $(\mu/\mu')\delta = 1.8 \times 10^{-7} \sim 2.3 \times 10^{-6}$ cm. Since the value of δ on an untreated surface is $3 \sim 4 \times 10^{-7}$cm, then $\mu/\mu' = 1/2 \sim 5$ may be obtained for B.C. and G.C. Since these values are not completely accurate, it was accepted for the purposes of Figure 5 and Table 3 that $\mu = \mu'$.

Since the terms other than the expotential terms in equation (7) are virtually constant with respect to V_α, and only the expotential terms are controlled by the current, the V-i characteristics may be derived very simply as follows when δ = 0 and α is known. <u>Viz.</u>, when the voltage for a given current i corresponds to $\delta = 0$ and $\delta = \delta$, the conditions may be respectively written as $(V_\alpha)_{\delta=0}$ and $(V_\alpha)_{\delta=\delta}$ and may be correlated as follows:

$$(V_a)_{\delta=\delta} = (V_a)_{\delta=0} + 4\phi_0\alpha\cdot\mu/\mu'\cdot\delta/L_0 + (V_a)_{\delta=0}\, 1/\alpha\cdot\mu/\mu'\cdot\delta/L_0 \tag{12}$$

as may be readily proven by equations (7) and (9). Figure 4 is a plot of the changes in α as a function of V_a as derived from equations (10) and (12). The V-i characteristics derived from an integration of this plot with equations (7) and (9) is given in Figure 5.

TABLE 3. V-i CHARACTERISTICS OF AN SiC BONDED DISK AS A FUNCTION

	calc.			obs.		
δ (Å)	(volt) $V_{i=1250\,A}$	(Amp) $i_{V=3000\,V}$	MΩ (10^6 ohm) $V=100\,V$	(volt) $V_{i=1250\,A}$	(Amp) $i_{V=3000\,V}$	MΩ (10^6 ohm) $V=100\,V$
0	4700	200	0.04			
20	5600	50	0.10			
30	6000	28	0.15	6000～ 6300	30～25	0.04～0.06
40	6500	17	0.20	6300～ 6500	20～17	0.05～0.08
52	7200	10	0.26	7100～ 7300	10～ 8	0.10～0.20
80	8500	3	0.40	8200～ 8500	～ 4	0.20～0.30
120	10500	1.5	0.60	10500～11000	2.5～1.7	0.25～0.45
160	12500	0.3	0.80			

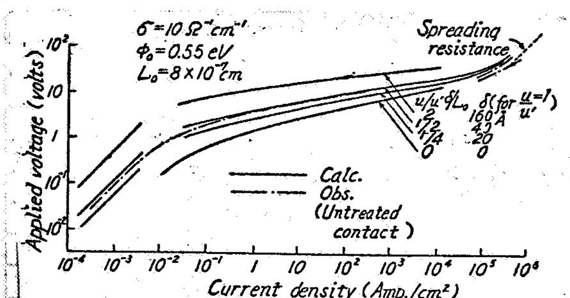

Figure 5. Theoretical V-i Characteristics as a Function of the Thickness of Oxide Film (by e.q.s. (7), (8) and (9)).

5.1 V-i Characteristics in the Low Voltage Region

It was determined experimentally that the SiC-SiC contact has an ohmic contact resistance under an applied load of ~ 0.5 volts or less. A current resulting from the tunnel effect tends to become saturated when the voltages are at about this level and, in accordance with our hypothesis, the current is proportional to voltage at V_i or less. Further as equation (8) shows, the changes in contact resistance as a function of oxide film thickness are proportional to δ; a conclusion which is quite consistent with the data given in Figure 2. These variations also appear concurrently with changes in the type of Schottky barrier. However, when oxidized SiC is etched with hydrogen fluoride, the resistance value is immediately restored. It therefore appears quite in order to conclude that these changes are dependent only on the changes in δ.

In accordance with this theory, V_i should increase in proportion to the increases in δ but the changes do not bear such relationship in practice. Accordingly, when δ is relatively large, the calculated current in the vicinity of $0.5 \sim 4\phi_0\mu/\mu'\delta/L_0$ volts deviates from the measured V-i characteristics. The δ -dependent deviation is the same as that which occurs as a result of the tunnel effect (current is related to the field at the point at which this current suddenly rises. We have found that the deviations of the calculated current from the measured current are indeed large.

5.2 V-i Characteristics in the High Voltage Region

Comparisons were then made with a pressure-formed sample constructed by mixing SiC grain with an appropriate binder and forming it into a 25-mm thick, 50 mm-diameter disk. The motivation for preparing the disk in this way were the aforesaid deviations that are caused by the material and the contact conditions when single crystal-like material is used, as well as the fear of an electrical breakdown under mechanical or electrical loads that might be attributed to the insulating material had the specimens been prepared from powder packed into an insulated tube as was the case in Section 3.

In this element, the number of SiC (SIC) connected in series was 354 while /608
the total horizontal contact area was 0.25 cm^2.

There have been two recent reports on V-i characteristics assuming a surface state. Stratton [2] holds that the SiC-SiC contact is a Mott-type of barrier contact since the static electric capacity of the barrier does not vary with changes in the voltage. However, this explanation is not satisfactory since it is not likely that a barrier, similar to that created when a single crystal is split, is formed immediately and, moreover, contact resistances on this order are exactly the same as those found in the normal SiC-SiC contact. On the other hand, Heywang [3] holds that the carrier passes through the Schottky barrier through the tunnel effect. However, the reading of 2.3 eV at a value of ϕ_0 is much too high on the basis of the contact potential in a metal-SiC contact as discussed in Section 2.1. Neither of the two explanations take into account the presence of the oxide film, and neither provides a rationale for the increase in contact resistance when the SiC is oxidized.

The changes in space charge as a function of the applied voltage may be determined by measurement of the electrostatic capacity. Mitchell [6], unlike Stratton, has determined that the electrostatic capacity remains constant up to V_i and drops concurrently with the drop in V_a when V_a is greater than V_i.

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